

# FINITE ELEMENT PROCEDURES FOR NON-LINEAR AEROELASTIC PROBLEMS

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In this paper non-linear finite element procedures for modeling aeroelastic problems are presented, with particular emphasis on large scale non-linear applications. The design and simulation of modern rotorcraft vehicles, such as helicopters and tilt-rotors, pose important computational challenges, and provides the motivation for much of the work presented here. In fact, many aspects of the numerical simulation of such vehicles are presently beyond the reach of the procedures used in industry. Simplified and often linearized equivalent models are routinely used, but their limitations can seriously undermine the reliability of the analysis and its effectiveness in the design process.

The first part of this talk focuses on the structural dynamics computational kernel of the problem, which is here formulated within the framework of flexible non-linear multibody dynamics. Using this technique, complex mechanisms of arbitrary topology can be modeled. In turn, this leads to the integration of large sets of stiff differential-algebraic equations that are solved using time integration schemes that ensure non-linear unconditional stability, a numerical property found extremely useful for solving realistic coupled problems [1]. Non-linear stability is achieved by mimicking at the discrete level the property of energy preservation of the governing differential equations. Further stabilization is obtained by damping the unresolved components of the computed solution, in a manner similar to that used in stiffly-accurate classical schemes. The importance of using non-linearly stable schemes is demonstrated here with an example dealing with the identification of the whirl-flutter boundaries of a next-generation tilt-rotor.

The second part of the paper focuses on finite element procedures for the fluid dynamics kernel of the aeroelastic problem. The approach relies on automated adaptive finite elements based on unstructured tetrahedral grids. The fluid field variables are computed using a parallel implicit adaptive code based on stabilized finite elements, which can solve compressible and incompressible flows, showing good scalability on a number of architectures. The adaptive procedures are based on mesh optimization, and produce high quality anisotropic elements for capturing anisotropic flow features of interest, such as boundary layers, shocks and wakes [2]. Finally, some promising ideas on ways to improve the a-posteriori error estimation that drives the adaptive process are presented.

## References

- [1] O.A. Bauchau, C.L. Bottasso, L. Trainelli, “Robust Integration Schemes for Flexible Multibody Systems,” *Comp. Methods Appl. Mech. Engrg.*, v. 192, p. 395–420, 2003.
- [2] C.L. Bottasso, “Anisotropic Mesh Adaption by Metric-Driven Optimization,” *Int. J. Num. Methods Engrg.*, under review.